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ABSTRACT

Objectives are listed describing the progression which students follow in learning to measure. These cbjectives follow a sequence that corresponds closely with the intellectual sequence found in students' learning. Grade-level reccmmendation charts follow the objectives. Topics dealt with are length, distance, area, volume, capacity, mass, and temperature. For each topic, non-numerical and numerical measurement objectives are listed. (MP)

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METRIC EDUCATION PROJECT

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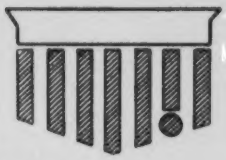

TEACHING MEASUREMENT TO CHILDREN:

GRADES K-6

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U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Overview

The following objectives describe the progression through which young people must be "escorted" in learning to measure. These objectives, while non-graded, have following them a set of grade level recommendation charts to facilitate their practical use in the classroom. These charts should only act as a guide to the teacher and may be revised according to the individual needs of a school district or classroom. Activities corresponding to these objectives are available through recently produced, commercially available products. Teachers should exercise extreme caution when selecting these activities and resources to insure that they coincide with appropriate techniques of teaching measurement endorsed by this project and much of the current research. Guidelines for selection of resources and sample activities are also available through this project.

The objectives and grade-level charts included deal with length, distance, area, volume, capacity, mass, and temperature. The objectives, as listed, do not specify any particular language of measurement, metric or imperial. This allows the user to determine the degree to which metric units will predominate. A recommended practice would be to use metric units whenever standard units for a quality are first being considered. English or imperial units should be presented, if at all, only after some degree of fluency has already been established with the corresponding metric units.

These measurement objectives follow a sequence that corresponds closely with the intellectual, developmental sequence found in children's learning. As such they should more nearly resemble the actual way in which children acquire their measurement skills. To some extent, therefore, these objectives are rather different from previously published listings.

One significant difference in this sequence is that children's first experiences are with Non-numerical Measurement, that is, direct physical comparison. Numerical Measurement is postponed from the early primary grades to be introduced later using actual physical models. This stage is followed by the development of Instrument Usage. The reader will find the objectives for each of the seven qualities sequenced in the following manner.*

I. Non-numerical Measurement

   A. Direct Comparisons

      1. Language Acquisition
      2. Sameness/Difference
      3. Ordering Relation
      4. Extreme-value Selection
      5. Rank Ordering

II. Numerical Measurement

   A. Physical Models

      1. Match and Describe
      2. Estimation
      3. Ordering Relation
      4. Rank Ordering

   B. Instrument Usage

      1. Calibration Concept
      2. Measuring
      3. Estimation
      4. Rank Ordering

*Certain measurement qualities do not lend themselves completely to the above sequence. These anomalies are dealt with in the specific introduction for that quality.

Another difference between the following sequence and past practice involves the progress through which a child is exposed to unit objects. The early and continued use of physical models for units of measure (before and concurrent with the use of calibrated measurement instruments) enhances the child's exper-

iences, making the units more concrete. The progression of the unit objects for all qualities (except temperature) should be:

A. Non-standard Units - the length (area, volume, etc.) of the unit objects used are arbitrary (examples: jelly beans, ice cream sticks, popcorn, marbles, paper clips)

B. Standard Units - the length (area, volume, etc.) of the unit objects used are of a standard system (metric or imperial).

Further, for some measurement qualities (especially length and distance) the unit objects themselves progress through a sequence. The child's first experiences are with homogeneous units; unit objects all having the same size. For example when working with non-standard units, children may use popsicle sticks, while meters might be used as the homogeneous standard unit. The child then moves into mixed units, where the set of unit objects have been partitioned into two classes: a base unit and a multiple or submultiple of that unit. In activities using non-standard units, 5 popsicle sticks might equal a length of string; using standard metric units, the meter would be partitioned into the submultiple, centimeter. This is dealt with further in each introduction.

In the learning of all measurement qualities, the critical role that the process of <u>estimation</u> plays cannot be overemphasized. This is the key to a student "internalizing" the measurement units used. The only way a student can become proficient at estimating is through practice and immediate reinforcement of that practice through verification of the estimate. Teachers should remember that estimates can never be "wrong" or "right"; they are all correct, some are just "closer" than others to the true value. Estimates become closer through continued use of the process.

METRICS AND SI

For many years there have been many different forms of the metric system being taught and used throughout the world. A good example of this is the MKS and CGS systems many of us learned in high school science. To provide universal uniformity in measurement, the International Conference on Weights and Measures has established the International System of Measurement, commonly called SI, as the accepted metric measurement system. Most countries have accepted SI as their official standard. The economic and political ramifications of this change will not be dealt with in this guide. The important educational points to remember when teaching measurement in the elementary grades are discussed briefly.

When introducing metric standard units it is important to make sure that the SI style of reading, writing, and pronouncing metric measurement terms are applied. This of course would insure all students are spelling and using metric terms the same way. This would include use of the decimal point, metric symbols, and other editorial guidelines. A pracical copy of these guidelines is available through the American National Metric Council (1625 Massachusetts Avenue, N.W.; Washington, D.C. 20036).

Despite these guidelines, some differences will appear, most of them being less than catastrophic. One example is the U.S. Metric Board's very recent adoption of the "er" spelling of meter and liter. Since the "-er vs. -re" controversy had continued for some time, many good resource materials on the market may use the -re ending. Students might be confused by this and so should be reassured that both spellings are used in the world but that in the U.S. the official spelling uses -er.

Teachers may note that there are no formal objectives dealing directly with the interrelationships within the standard system of measurement and therefore no provision to teach students the "big picture". This has been purposely postponed until junior high school. The reasons are multi-faceted. The importance of measurement instruction in the elementary grades is to have students develop fluency with the common units of measure. Through this approach many students will discover relationships between the units. Formal instruction of these relationships before the student is fluent can cause confusion and the misconception that the system is "too complicated". Only after students have a comfortable grasp of the basic units of SI, should the system's structure as a whole be presented.

Introduction to Length

The quality of length is usually the first measurement unit to be introduced to children. Children do not conserve length until the ages of 7 to 8.5 years. That is, they realize that the length of an object remains invarient even after the object is moved or partitioned. Primary teachers should be aware of this fact before planning measurement activities using length. Many non-numerical measurement experiences, using direct physical comparisons of the objects, should be planned before introducing physical models for units of measure. The student should also have much exposured to these units of measure before introducing measuring instruments.

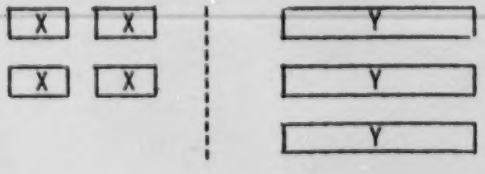
The set of unit objects referred to in Section II-A of length should progress through the following sequence:

A. Non-standard units - the length of the unit objects used are arbitrary (ex. peanuts, ice creame sticks, etc.)

1. Homogeneous: all the unit objects have the same length

2. Mixed: the unit objects are partitioned into 2 subsets (each homogeneous) with the unit objects in one subset significantly longer or shorter than the objects in the other subset.

For example:



A length is described as requiring so many X's and so many Y's. Ideally, we seek to have students come to maximize the Y's (the longer unit) while minimizing the X's (the shorter unit). In practice, it is wise if the Y's unit's length is an integral multiple of the X unit's length.

B. Standard units - the length of the unit objects used are of a standard length (metric or imperial)

1. Homogeneous: all the unit objects have the same length

2. Mixed: objects partitioned into 2 subsets, one a multiple (or submultiple) of the other. For example: meter-centimeter or inch-foot.

   It is at this point that relationships between prefixes are explored in metric system, as they occur, not all at once.

The mixed stages noted above should be introduced only after many homogeneous activities, during the later primary or early intermediate grades. The suggested introduction of non-standard and standard units can be noted in the grade level charts beginning on page -L6-.

Length

I. Non Numerical Measurement

A. Direct Comparisons

1. Language Acquisition - given an object, the structure of which clearly illustrates "length" (ex. pencil, spoon, stick, crayon, etc.) the student will verbally identify appropriate aspect of the object as its "length."

2. Sameness/Difference - presented two objects the student will indicate whether they are the same or different length - OR - presented a set of three or more objects the student will select a pair of objects from the set which are either the same or different length, by directly, physically comparing their lengths.

3. Ordering Relation - presented two objects the student will determine which is the longer (or shorter) object by comparing them directly.

4. Extreme-value Selection - presented a set of three or more objects the student will determine the longest (or shortest) object by comparing them directly.

5. Rank Ordering - given a set of objects the student will rank them from shortest to longest (or vice versa). The ranking is determined by direct physical comparison.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given an object, and a set of objects of equal length to serve as "unit objects" the student will produce a set of unit objects laid end to end equal in total length to the given object, and will describe the given object's length in terms of the unit used.

For example, the "unit objects" might be toothpicks. The student would lay them end to end until they matched the length of some object, and then describe the object's length as "7 toothpicks."

2. Estimation - given an object and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions), the student will estimate the length of the given object in terms of the specified unit. (The estimate should be followed immediately with an opportunity to verify by matching!)

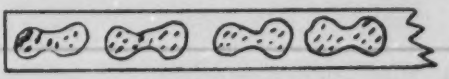
3. Ordering Relation - given two objects and a set of "unit objects", the student will determine which is the longer (or shorter) object by matching each with a set of unit objects, describing each in terms of the unit used, and by concluding finally that the object requiring the "greater number" of unit objects is the "longer" object (or vice versa).

4. Rank Ordering - given a set of objects, and unit objects, the student will rank the objects from shortest to longest (or vice versa) by matching each object with a set of unit objects, describing each in terms of the units used, and then ranking them based on their numerical lengths (as in #3 above).

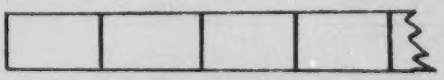
B. Instrument Usage

1. Calibration Concept - given a set of "unit objects" and an uncalibrated ruler (a blank stick, piece of cardboard, acetate, etc.) the student will calibrate the ruler by matching and recording, i.e.

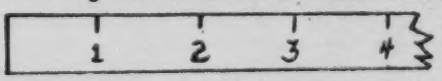
a) matching the unit objects to the rule and recording their presence (tape on, pencil in, etc.) ex. peanuts



b) draw lines to represent their presence



c) numbering calibrations drawn above



Ruler should be used (as in #3 below) after each stage above.

Length (cont.)

2. Measuring - given an object and a calibrated rule(r) the student will measure the given object and describe its length in the unit calibrated.

   These measurements should be: first, to the nearest submultiple calibrated on the ruler, and finally to the limit of precision of the instrument.

3. Estimation - given an object and the name of a unit with which (s) he is familiar (i.e. with which he has performed a number of measurements) the student will estimate the length of the given object in terms of the unit specified.

   The estimate should be followed immediately with an opportunity to verify the quality of the estimate by measuring the length with a ruler. Remember (and impress): No estimates are "wrong", some are just better than others.

4. Rank Ordering - given a set of objects and a calibrated rule(r) the student will rank the objects from shortest to longest (or vice versa) by measuring each object with the rule(r) and ranking them according to the measurements obtained..

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	X
2. ESTIMATION	X	
3. ORDERING RELATION	X	
4. RANK ORDERING	X	

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	X
2. ESTIMATION	X	X
3. ORDERING RELATION	X	X
4. RANK ORDERING	X	X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT	X	X
2. MEASURING	X	X
3. ESTIMATION	X	
4. RANK ORDERING	X	

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		X
2. ESTIMATION	X	X
3. ORDERING RELATION	X	X
4. RANK ORDERING	X	X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		X
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Length

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

Introduction to Distance

The difference between length and distance is subtle but nonetheless important. Children, particularly at the primary level, can perceive the length of an object within their grasp more readily than they can a distance between two objects. At this level, children can readily perceive a real attribute of an object (length, color, shape, etc.) but they have difficulty in perceiving the conceptual value of distance. In fact, distance is not a physical attribute of one object at all, but is a relationship between two objects. A relationship of this type is much more complex than the basic attribute of an object's length. Therefore, as expected, the grade level charts indicate that the objectives for distance are introduced at a later time than those for length.

Because of the complexity of perceiving distance, children also have difficulty in comprehending its linearity. That is, they do not see the distance between two objects as being a straight line. This misperception must be attended to before actual direct comparisons of distances can be successful.

The set of "unit objects" referred to in Section II-A should progress through the following sequence (See -L1- for further explanation):

1) a homogeneous set of objects of arbitrary but equal length (ex. peanuts)

2) a mixed set of objects partitioned into two (2) homogeneous subsets, each containing objects of arbitrary but equal (=) lengths (ex. peanuts and ice cream sticks)

3) a homogeneous set of objects of a standard unit length (ex. centicubes)

4) a mixed set of objects partitioned into two homogeneous subsets, each containing objects of a standard unit length - with one set being either a multiple or submultiple of the other (m-cm, or ft.-in.)

Again estimation plays an important role in developing this quality. It should be emphasized that a child's estimate can never be wrong but can come closer to the actual measure with increased practice followed by immediate verification.

Distance

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given two objects (or reference points) the student will verbally identify the linear space between them as the "distance" which separates them.

2. Sameness/Difference - given two pairs of objects (or reference points) in which the distance between the first pair of objects is clearly different (or clearly the same) than the distance between the second pair of objects, the student will indicate that the two pairs of objects are different (the same) distances apart.

3. Ordering Relation - presented with three objects (or reference points of clearly different distances apart, the student will determine with respect to one of the objects, which of the other two objects is closer (farther) by comparing them directly.

4. Extreme-value Selection - presented with a collection of objects or reference points) the student will determine with respect to one object which of the remaining objects is the closest (farthest) by comparing the distances directly.

5. Rank Ordering - given a collection of objects (or reference points) the student will, with respect to one object rank the remaining objects from closest to farthest (or vice versa). The ranking is determined by direct physical comparison.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given two objects (or reference points) and an appropriate set of objects of equal length to serve as "unit objects" the student will produce a set of unit objects approximately

equal to the total distance between the given two objects. The student will then describe the determined distance in terms of the unit used.

For example, a student may use erasers as the "unit object" and, laying them end to end, would match the distance of two objects. This distance would then be described as say "14 erasers".

2. Estimation - given two objects (or reference points) and the name of a unit object with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions), the student will estimate the distance between the given objects in terms of the specified unit. (The estimate should be followed immediately with an opportunity to verify by matching!)

3. Ordering Relation - given three objects (or reference points) the students will determine with respect to one of the objects, which of the other two objects is closer (farther) by matching each distance with a set of unit objects, describing each distance in terms of that unit, and concluding that the "smaller (greater) number" of unit objects is the closer (farther) distance.

4. Rank Ordering - given a collection of objects (or reference points) the student will, with respect to one of the given objects, rank the remaining objects from closest to farthest (or vice versa) by matching each distance with a set of unit objects, describing the results and ranking them according to their numerical distances.

B. Instrument Usage

1. Calibration Concept - See Length II-B-1

2. Measuring - given two objects (or reference points) and a calibrated rule(r) or tape, the student will measure, then describe the distance between the objects in terms of the unit calibrated.

These descriptions should first be: first, to the nearest whole unit, then later to the nearest submultiple calibrated, and finally to the limit of precision of the instrument.

Distance (cont.)

3. Estimation - given two objects (or reference points) and the name of a unit with which (s)he is familiar (i.e. with which (s)he has performed a number of measurements) the student will estimate the length of the given object in terms of the unit specified. The estimate should be followed immediately with an opportunity to verify the quality of the estimate by measuring the distance with a ruler or tape.

4. Rank Ordering - given a collection of objects (or reference points) and a calibrated rule(r) or tape, the student will, with respect to one of the given objects, rank the remaining objects from closest to farthest (or vice versa) by measurements determined with the ruler or tape.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	X
2. ESTIMATION	X	X
3. ORDERING RELATION	X	X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT	X	
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		X
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Distance

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

Introduction to Area

The quality of area, the measure of a plane surface, seems to be a difficult quality for children to perceive. There are techniques and materials, though, which can assist the child in understanding the concept of area.

The first is the use of superimposable surfaces in achieving the non-numerical objectives. Superimposable surfaces can be made using clear or colored acetate paper, tracing paper, tissue paper, or clear plastic shapes. These objects can then have their areas directly compared (as in Section I-A). The student can actually see the two areas and the relationships between them. Superimposable surface activities should be followed by activities using non-superimposable (opaque) surfaces. These objects can be compared again through direct physical comparison through "partitioning". Cutting up one paper surface to "cover" another surface and observing the results is one good way to directly compare two non-superimposable surfaces.

As in the other quality objectives, the unit objects discussed in Section II-A should progress through the following sequences: (see -L1- for further information):

1) a congruent set of unit surfaces, all being equal but <u>arbitrary</u> areas (ex. playing cards, counting chips)

2) a congruent set of surfaces, all of equal and <u>standard</u> area (ex. 1 side of a centicube = 1 cm^2)

It is important to note that unlike length and distance, this area sequence does not include "mixed" unit objects. All unit objects referred to in this section are homogeneous.

In most classrooms, students working on activities of this unit have not previously created a calibrated instrument for area. The resulting area grids described in the objectives of Section II-B will fill this void. Area grids are most helpful to students in visualizing, thus internalizing, area. They are also convenient for verification of area estimates.

Area

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given a plane surface, the student will identify the aspect of it known as its "area."

2. Sameness/Difference - given two surfaces of clearly different (or the same) areas, the student will indicate if they are the same or different in area by directly comparing the two areas.

3. Ordering Relation - given two surfaces of clearly different areas, the student will indicate which surface has greater area (covers more) by directly comparing the two areas.

4. Extreme-value Selection - given a set of surfaces of clearly different areas the student will select the one with the greatest (least) area by directly comparing the two areas.

5. Rank Ordering - given a set of surfaces of clearly different areas the student will rank the surfaces from the one with greatest to least area (or vice versa) by directly comparing their areas.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given a surface, and a set of congruent objects (of equal area and shape) to serve as "unit objects" the student will produce a set of unit objects equal (approximately) to the total area of the given surface. The student will then describe the determined area in terms of the number of units used.

For example, the unit objects might be plastic chips all of some polygonal shape. The student would "cover" the surface with the necessary chips until they matched the given surface and then describe the areas as say "23 chips".

Area (cont.)

2. Estimation - given a surface and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions) the student will estimate the area of the surface in terms of the unit specified. (The estimate should be followed immediately with an opportunity to verify by matching!)

3. Ordering Relation - given two surfaces of clearly different area and a set of "unit objects", the student will indicate which of the two surfaces has the greater (lesser) area by matching each surface with the set of unit objects, describing each in terms of the unit used and comparing the numerical results.

4. Rank Ordering - given a set of surfaces of clearly different areas the student will rank them from the one with the greatest to the one with the least area (or vice versa) using the same method used in #3 above.

B. Instrument Usage

1. Calibration Concept - given a set of unit objects (congruent surfaces) and a clear acetate (or other surface on which the objects can be traced) the student will calibrate the instrument by matching and recording (i.e., make an area grid).

2. Measuring - given a surface, and a calibrated area grid the student will measure, then describe the area of the given surface to the nearest whole unit.

3. Estimation - given a surface and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of measurements) the student will estimate the area of the given surface in terms of the unit specified. The estimate should be followed immediately with an opportunity to verify the quality of the estimate through measuring.

4. Rank Ordering - given a set of surfaces the student will rank them from the one with the greatest area to the least area (or vice versa) by measuring the surfaces with an area instrument (grid) and comparing the numerical results.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	
2. ESTIMATION	X	
3. ORDERING RELATION	X	
4. RANK ORDERING	X	

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	X
2. ESTIMATION	X	X
3. ORDERING RELATION	X	X
4. RANK ORDERING	X	X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		X
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		X
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Area

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT	X	X
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING	X	X

Volume vs Capacity

While volume and capacity are very closely related concepts, and can in fact be measured with the same standard units, a distinction should be made between them. The term "volume" refers to the space an object occupies, while "capacity" to the space within its interior. Both are frequently referred to as just volume. Occasionally, the former is referred to as "dry volume" and the later as "wet volume".

In teaching measurement to children it is important that we isolate these related concepts, especially in their early presentation. Failure to do so could lead to considerable confusion. The need is most critical during the language acquisition period. Later, when developing activities for teaching units of measure for volume, it would not be inappropriate to deal with both concepts concurrently.

A critical note is in order, however. When attempting to make relative judgements regarding the volume of two irregular objects, it is common to employ a technique known as displaced volume measurement. Each object is placed into a vessel containing a given volume of sand (or other suitable substance). The differing levels to which the sand is displaced are noted; with the object displacing more sand having the greater volume. This technique is NOT appropriate for most elementary children. Its use requires that the children conserve displaced volume, an ability which frequently is not acquired until junior-high school years. Volume activities requiring numerical measurement should be limited to objects whose shape's are commensurate with the units used (i.e. if cubic units, then objects which are rectangular solids or unions thereof.)

Therefore, a cautionary attitude is most appropriate in dealing with volume/capacity issues with primary children. We can not assume they

approach the issue from our adult perspective. Primary children can deal with the issue; but wherever relative, non-numerical judgements are required, the differences between containers should be of large orders of magnitude.

Though the pedogogical distinctions made above should be considered important, we are not attempting to change deeply rooted linguistic patterns. We wish to avoid confusing young (and older) students by a strict semantic rule. This is especially necessary when many educational materials as well as practical, consumer resources use "volume" when referring to both volume (as defined above) and capacity. Students should not be overly concerned about this. Teachers, though, should attempt to use the term "capacity" when <u>introducing</u> activities which deal exclusively with this concept.

Introduction to Volume

Volume is a very sophisticated quality for children to deal with.* Many children do not come to conserve volume until their early teens. Our instructional programs need to take cognizance of this fact. With respect to volume, the emphasis in the grades should be on concrete manipulative experiences.

The objectives in Section II-A seek to deal with this issue. The "unit objects" referred to in this section should progress through the following sequence:

1) a homogeneous set of objects of <u>arbitrary</u> but equal units of volume (ex. wooden cubes, popcorn, jelly beans)

2) a homogeneous set of objects of a <u>standard unit</u> of volume (ex. centicubes)

3) a mixed set of objects partitioned into two homogenous subsets, each containing objects of a <u>standard unit</u> of volume - with one set being either a multiple or sub-multiple of the other (dm^3 - cm^3, or $ft.^3$ - $in.^3$)

It should also be noted that there are no objectives listed for instrument measurement with volume. There is no instrument which <u>directly</u> measures volume. Measurement by displacement is an indirect process.

Linear measures, and an assortment of formulas, exist to derive the volumes of many common solids, but these also do not constitute direct measurements of volume. In the later intermediate grades, the development of a formula for rectangular solids (l x w x h) should be introduced. This will then set the stage for other abstractions dealing with volume which have been postponed until the junior high years.

*See page -V1- for a detailed discussion of the volume/capacity dichotomy.

Volume

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given an object the student will identify the appropriate aspect of it as its "volume".

2. Sameness/Difference - presented two objects clearly differing in volume (or clearly the same in volume), the student will indicate if they are same or different by directly, physically comparing their volumes.

3. Ordering Relation - presented two objects of clearly different volumes, the student will indicate which has the greater (lesser) volume of the two by directly, physically comparing their volumes.

4. Extreme-value Selection - given a set of objects of clearly different volumes, the student will select the object having the greatest (least) volume by directly, physically comparing their volumes.

5. Rank Ordering - given a set of objects of clearly different volumes, the student will rank the objects from greatest to least volumes (or vice versa), by directly, physically comparing the objects' volumes.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given an object, and a set of objects of equal volume to serve as "unit objects" the student will produce a set of unit objects equal in volume to the given object and then describe this set (the objects' volume) in terms of the number of "unit objects" used.

For example, the unit objects might be wooden cubes. The student would arrange them until they matched the shape (volume) of some given rectangular object and then describe the volume as say "20 wooden cubes".

Volume (cont.)

2. Estimation - given an object and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions) the student will estimate the volume of the given object in terms of the specified unit. (The estimate should be followed immediately with an opportunity to verify by matching!)

3. Ordering Relation - given two objects of clearly different volumes, the student will indicate which object has the greater (or lesser) volume by matching each of the volumes with a set of unit objects, describing each in terms of the number of units used, and comparing the numerical results.

4. Rank Ordering - given a set of objects of clearly different volumes, the student will rank them from greatest to least volume (or vice versa) using the same method used in #3 above.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage *

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage*

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage*

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	
2. ESTIMATION	X	
3. ORDERING RELATION	X	
4. RANK ORDERING	X	

B. Instrument Usage*

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		X
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage *

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage*

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Volume

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage*

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

*NOT APPLICABLE - SEE INTRODUCTION

Introduction to Capacity

The quality of capacity refers to the measure of the space within an objects' interior. While all objects have a certain volume, not all objects have a capacity, able to contain a given volume of material. In this section all objects which have capacity are referred to as containers.*

The objectives listed under non-numerical measurement of capacity reflect the fact that direct comparison with respect to capacity may be somewhat less direct than with other qualities. In making direct comparisions with length, for example, one need only place the objects near each other. The visual stimulii provided are usually sufficient to allow a relative judgement to be made. With capacity, however, merely placing the two subject containers near each other, may not always afford sufficient information to allow a reasonable judgement. In such instances, the judgement can be facilitated by filling one of the containers completely with an available substance (water, sand, popcorn) and then pouring its contents into the other container. The relative capacity is then clearly illustrated. This technique, however, is appropriate only for those students who have come to conserve volume, an ability rarely acquired before fourth grade and often not until junior high.

The "unit objects" referred to in Section II-A should progress through the following sequence:

1) a homogeneous set of objects of arbitrary but equal volume (ex. peanuts, marbles, wooden cubes)

2) a homogeneous set of objects of standard unit of volume (ex. centicubes)

*For page -V1- for a detailed discussion of the volume/capacity dichtomy.

Unlike volume, instruments do exist for measuring capacity. Objectives on Instrument Usage are included in this section.

Capacity

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given a container the student will identify the appropriate aspect of it as its "capacity".

2. Sameness/Difference - presented two containers clearly differing in capacity (or clearly the same capacity), the student will indicate if they are of the same or different capacity by directly physically comparing their capacities.

3. Ordering Relation - presented two containers of clearly different capacities, the student will indicate which of the containers has the greater (lesser) capacity by directly, physically comparing their capacities.

4. Extreme-value Selection - given a set of containers of clearly different capacities the student will select the container with the greatest (least) capacity by directly physically comparing their capacities.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given a container, and a set of objects of equal volume to serve as "unit objects" the student will produce a set of unit objects equal in volume to the capacity of the given container and then describe this set in terms of the number of "unit objects" used.

   For example, the unit objects might be marbles. The student would arrange them until they filled some given container and then describe the capacity as say "13 marbles."

2. Estimation - given a container and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions), the student will estimate the capacity of the given container in terms of the specified unit. (The estimate should be followed immediately with an opportunity to verify by matching!)

Capacity (cont.)

3. Ordering Relation - given two containers of clearly different capacities, the student will indicate which of the containers is the larger (or smaller) (i.e., more or less capacity) by matching each of the capacities with a set of "unit objects," describing each in terms of the number of units used, and then comparing the numerical results.

4. Rank Ordering - given a set of containers of clearly different capacities, the student will rank them from least to greatest capacity (or vice versa) using the same method as in #3 above.

B. Instrument Usage

1. Calibration Concept - given a set of containers of equal capacity to serve as "unit objects," and an uncalibrated vessel (cylinder), the student will calibrate the instrument by matching and recording.

2. Measuring - given a container and a calibrated cylinder, the student will describe the given container's capacity in terms of the unit calibrated.

These descriptions should first be to the nearest whole unit, later to the nearest submiltiple of the base unit calibrated, and finally to the limit of precision of the instrument.

3. Estimation - given a container and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of measurements) the student will estimate the capacity of the given container in terms of the unit specified. The estimate should be followed immediately with an opportunity to verify the quality of the estimate through measuring.

4. Rank Ordering - given a set of containers of clearly different capacities the student will rank them from greatest to least capacity (or vice versa) by measuring their capacities as in #2 above and then comparing the numerical results.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	X
2. ESTIMATION	X	X
3. ORDERING RELATION	X	X
4. RANK ORDERING	X	X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT	X	X
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING	X	X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Capacity

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		X
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

Introduction to Mass

Throughout the following objectives the quality under consideration is referred to as "mass". This attribute is commonly referred to as "weight". While the distinction is technically correct, it will be some time before such a deeply entrenched language pattern is changed. It is, therefore, recommended that teachers should attempt to use the term "mass" wherever its use is appropriate; but accept from children either the term mass or weight as though they were interchangeable. When children are intellectually prepared to comprehend the distinction, however, the terms should then be used correctly.

Direct physical comparison of differing masses, not unlike capacity, can be somewhat less than direct. The use of a two-pan balance (NOT a dial scale) can serve as an intermediary readily comprehended by very young children. In situations where relative differences in mass are not readily apparent, the two-pan balance should be utilized.

The unit objects referred to in the Physical Models section should progress through the following sequence:

1) a homogeneous set of objects of <u>arbitrary</u> but equal mass (ex. marbles)

2) a mixed set of objects partitioned into two (2) homogeneous subsets, each containing objects of <u>arbitrary</u> but equal mass (ex. peanuts and marbles)

3) a homogeneous set of objects of a <u>standard unit</u> mass (ex. centicubes)

4) a mixed set of objects partitioned into two homogeneous subsets, each containing objects of a <u>standard unit</u> mass - with one set being either a multiple or submultiple of the other (kg-g, oz.-lb.)

Mass

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given an object the student will identify the appropriate aspect of it as its "mass".

2. Sameness/Difference - presented two objects clearly differing in mass, (or clearly the same), the student will indicate if they are of the same or different mass by directly, physically comparing their masses.

3. Ordering Relation - presented two objects of clearly different mass, the student will indicate which of the objects has the greater (lesser) mass by directly comparing their masses.

4. Extreme-value Selection - presented a set of objects of clearly different mass, the student will select the object with the greatest (least) mass by directly comparing their masses.

5. Rank Ordering - given a set of objects of clearly different mass, the student will rank the objects from greatest to least (or vice versa) by directly, physically comparing their masses.

II. Numerical Measurement

A. Physical Models

1. Match and Describe - given an object, and a set of objects of equal mass to serve as "unit objects" the student will produce a set of unit objects equal in mass to the given object and then describe this set in terms of the number of "unit objects" used.

For example, the unit objects might be jelly beans. The student would stack them on a 2-pan balance until they balanced the mass of some given object, count them and describe the mass as say "21 jelly beans".

Mass (cont.)

2. Estimation - given an object and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of directed descriptions), the student will estimate the mass of the given object in terms of the specified unit. (The estimate should be followed immediately with an opportunity to verify by matching!)

3. Ordering Relation - given two objects of clearly different mass, the student will indicate which has the greater (lesser) mass by matching each of the masses with a set of "unit objects", describing each in terms of the number of units used, and then comparing the numerical results.

4. Rank Ordering - given a set of objects of clearly different mass, the students will rank them from greatest to least mass (or vice versa) using the same method used in #3 above.

B. Instrument Usage

1. Calibration Concept - given a set of objects of equal mass to serve as "unit objects", and an uncalibrated scale, the student will calibrate the instrument by matching and recording.

2. Measuring - given an object and a calibrated scale, the student will describe the given object's mass in terms of the unit calibrated.

These descriptions should first be to the nearest whole unit, later to the nearest submultiple of the base unit calibrated, and finally to the limit of precision of the instrument.

3. Estimation - given an object and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of measurements) the student will estimate the mass of the given object in terms of the unit specified. The estimate should be followed immediately with an opportunity to verify the quality of the estimate through measuring.

Mass (cont.)

4. Rank Ordering - given a set of objects of clearly different mass, the student will rank them from greatest to least mass (or vice versa), by comparing the numerical results of measurements obtained using a scale.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	X
5. RANK ORDERING	X

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE	X	
2. ESTIMATION	X	
3. ORDERING RELATION	X	
4. RANK ORDERING	X	

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		X
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT	X	X
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING	X	X

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Mass

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		X
3. ORDERING RELATION		X
4. RANK ORDERING		X

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		X
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		X

Introduction to Temperature

The practical use of temperature in everyday experiences is an obvious rationale for introducing this quality to students through a formal objective program.

Many objectives, particularly those dealing with direct models, do not readily lend themselves to a realistic teaching approach. We try to create many everyday experiences that will help students "internalize" key temperature levels. This leads us to see the importance of direct comparison and estimation activities.

One word of metric caution, many published (or announced) temperature levels are given in both metric and imperial degrees, simultaneously. This does not help, and in fact hinders, the student (and adult) in attaining a fluency with degrees Celsius without the Fahrenheit "crutch". Every attempt should be made to insure the separation of these two temperature scales.

Temperature

I. Non-numerical Measurement

A. Direct Comparison

1. Language Acquisition - given an object (or environment) the student will identify the appropriate aspect of it as its "temperature".

2. Sameness/Difference - presented two objects having clearly different temperatures (or clearly the same temperature) the student will indicate if they have the same or different temperature.

3. Ordering Relation - presented two objects having clearly different temperatures, the student will indicate which is colder (hotter, warmer) by physically (feeling) testing the objects.

II. Numerical Measurement

B. Instrument Usage

2. Measuring - given an object (or environment) and a calibrated scale (thermometer), the student will describe the given object's temperature in terms of the unit calibrated.

These descriptions should first be to the nearest degree, and then to the limit of precision of the instrument used.

3. Estimation - given an object (or air space) and the name of a unit with which (s)he is familiar (i.e. with which he has performed a number of measurements) the student will estimate the temperature of the given object in terms of the unit specified. The estimate should be followed immediately with an opportunity to verify the quality of the estimate through measuring.

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: K

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 1

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 2

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	X
2. SAMENESS/DIFFERENCE	X
3. ORDERING RELATION	X
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING	X	
3. ESTIMATION		
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 3

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 4

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING	X	X
3. ESTIMATION	X	X
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 5

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		

COMPREHENSIVE METRIC EDUCATION PROJECT

QUALITY: Temperature

GRADE: 6

[X] Indicates appropriate for this grade level

I. Non-numerical Measurement

A. Direct Comparison

1. LANGUAGE ACQUISITION	
2. SAMENESS/DIFFERENCE	
3. ORDERING RELATION	
4. EXTREME-VALUE SELECTION	
5. RANK ORDERING	

II. Numerical Measurement

A. Physical Models

	Non-Standard Units	Standard Units
1. MATCH AND DESCRIBE		
2. ESTIMATION		
3. ORDERING RELATION		
4. RANK ORDERING		

B. Instrument Usage

	Non-Standard Units	Standard Units
1. CALIBRATION CONCEPT		
2. MEASURING		X
3. ESTIMATION		X
4. RANK ORDERING		